

**WHAT IS CLAIMED IS:**

1        1.        A punch for forging a metallic plate member, comprising:  
2                a first die, adapted to be opposed to a first face of the plate member;  
3                a second die, adapted to be opposed to a second face of the plate  
4 member;  
5                a plurality of first projections, provided on the first die and arranged in  
6 a first direction with a fixed pitch, each of the first projections being elongated  
7 in a second direction perpendicular to the first direction; and  
8                a plurality of second projections, provided on the second die and  
9 arranged in the first direction with the fixed pitch, each of the second  
10 projections being elongated in the second direction and provided with a  
11 concave portion extending in the second direction at a distal end portion  
12 thereof,  
13                wherein the plate member is sandwiched between the first die and the  
14 second die so that the first projections and the second projections are cut into  
15 the plate member in a third direction orthogonal to the first direction and the  
16 second direction, to perform a first forging work.

1        2.        The punch as set forth in claim 1, further comprising a third die,  
2 adapted to be opposed to the second face of the plate member on which the  
3 first forging work has been performed,  
4                wherein the plate member is sandwiched between the first die and the  
5 third die so that only the first projections are cut into the plate member in the  
6 third direction, to perform a second forging work.

1     3.     The punch as set forth in claim 1, wherein the second die is arranged  
2     such that each of the second projections is opposed to a gap defined between  
3     adjacent ones of the first projections.

1     4.     The punch as set forth in claim 1, wherein the second die is arranged  
2     such that each of the second projections is opposed to an associated one of  
3     the first projections.

1     5.     The punch as set forth in claim 1, wherein the concave portion is  
2     arranged at a center portion of each of the second projections with regard to  
3     the second direction.

1     6.     The punch as set forth in claim 1, wherein the concave portion has an  
2     arcuate shape when viewed from the first direction.

1     7.     The punch as set forth in claim 1, wherein the concave portion is  
2     formed with a plurality of flat faces.

1     8.     The punch as set forth in claim 1, wherein a convex portion is formed  
2     on a bottom portion of the concave portion.

1     9.     The punch as set forth in claim 8, wherein the convex portion has a  
2     height such an extent that a plurality of concave portions are substantially  
3     defined by the convex portion.

1 10. The punch as set forth in claim 1, wherein a recess portion is formed  
2 at a bottom portion of the concave portion.

1 11. The punch as set forth in claim 1, wherein a length of the concave  
2 portion in the second direction is  $\frac{2}{3}$  or less of a length of each of the second  
3 projections in the second direction.

1 12. The punch as set forth in claim 1, wherein a ratio of a depth of the  
2 concave portion with respect to a length of the concave portion in the second  
3 direction falls within a range of 0.05 to 0.3.

1 13. The punch as set forth in claim 1, wherein a ratio of a depth of the  
2 concave portion with respect to a height of each of the second projections falls  
3 within a range of 0.5 to 1.

1 14. The punch as set forth in claim 1, wherein at least the concave  
2 portion of each of the second projections is finished with either mirror finishing  
3 or chromium plating.

1 15. The punch as set forth in claim 1, wherein each of the second  
2 projections has a wedge-shaped cross section when viewed from the second  
3 direction.

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1     16.     The punch as set forth in claim 15, wherein a distal end angle of the  
2     wedge-shaped cross section is 90 degrees or less.

1     17.     The punch as set forth in claim 1, wherein the fixed pitch is 0.3 mm or  
2     less.

1     18.     The punch as set forth in claim 2, wherein:  
2             the third die is formed with a pair of third projections arranged in the  
3     second direction and elongated in the first direction so as to define a groove  
4     therebetween; and  
5             each of the third projections has a flat distal end face.

1     19.     The punch as set forth in claim 18, wherein the concave portion in the  
2     second die and the groove in the third die are placed at a same position with  
3     respect to the plate member in connection with the second direction.

1     20.     The punch as set forth in claim 18, wherein sloped flat faces  
2     continued from the flat distal end face are provided at both end portions in the  
3     first direction of each of the third projections, such that a portion closer to an  
4     end in the first direction of each of the third projections is more separated from  
5     the first die.

1     21.     The punch as set forth in claim 18, wherein a depth of the groove falls  
2     within a range of 0.05 mm to 0.15 mm, and a length in the second direction of  
3     the groove falls within a range of 0.5 mm to 1 mm.

1     22.     The forging punch as set forth in claim 2, wherein the second die and  
2     the third die are arranged such that the first forging work and the second  
3     forging work are performed in a progressive manner.

1     23.     A forging apparatus comprising the punch as set forth in claim 1.

1     24.     A method of forging a metallic plate member, comprising steps of:  
2             providing a first die, in which a plurality of first projections are  
3     arranged in a first direction with a fixed pitch, each of the first projections being  
4     elongated in a second direction perpendicular to the first direction;  
5             providing a second die, in which a plurality of second projections are  
6     arranged in the first direction with the fixed pitch, each of the second  
7     projections being elongated in the second direction and provided with a  
8     concave portion extending in the second direction at a distal end portion  
9     thereof;  
10            providing a third die, in which a pair of third projections arranged in  
11     the second direction and elongated in the first direction so as to define a  
12     groove therebetween, each of the third projections having a flat distal end face;  
13            opposing the first die to a first face of the plate member while  
14     opposing the second die to a second face of the plate member;  
15            performing a first forging work by sandwiching the plate member with  
16     the first die and the second die in a third direction orthogonal to the first  
17     direction and the second direction, so as to generate a plastic flow of a  
18     material in the plate member into gaps defined between the first projections

19 while generating a plastic flow of the material into the concave portion of each  
20 of the second projection;  
21 opposing the third die to the second face of the plate member, after  
22 the first forging work; and  
23 performing a second forging work, by sandwiching the plate member  
24 with the first die and the third die in the third direction, such that the flat distal  
25 end face of each of the third projections generates a plastic flow of the material  
26 into the gaps between the first projections, while a protrusion formed on the  
27 plate member by the concave portion is received by the groove,  
28 wherein a plurality of recesses formed by the first projections are  
29 partitioned by partition walls formed by the material flown into the gaps  
30 between the first projections.

1 25. A method of manufacturing a liquid ejection head, using the forging  
2 method as set forth in claim 24, the manufacturing method comprising steps of:  
3 forming a through hole in each of the recesses so as to communicate  
4 each of the recesses with the second face of the plate member;  
5 joining a sealing plate onto the first face of the plate member so as to  
6 seal the recesses;  
7 providing a metallic nozzle plate formed with a plurality of nozzles;  
8 and  
9 joining the nozzle plate, with an adhesive agent, onto the second face  
10 of the plate member such that each of the nozzles is communicated with an  
11 associated one of the recesses via the through hole,  
12 wherein the liquid ejection head is configured such that liquid droplets

13 are ejected from the nozzles by pressure fluctuation generated in liquid  
14 contained in the recesses.

1 26. The manufacturing method as set forth in claim 25, wherein a plurality  
2 of dents formed by the second projections and remained on the second face of  
3 the plate member are used to receive excess adhesive agent when the nozzle  
4 plate is joined onto the second face of the plate member.

1 27. The manufacturing method as set forth in claim 25, wherein a height  
2 of one of the flat distal end faces of the third projections which is closer to a  
3 portion where the through hole is to be formed is lower than the other one of  
4 the flat distal end faces.

1 28. A liquid ejection head manufactured by the method as set forth in  
2 claim 25, wherein a plurality of dents are arranged on the second face of the  
3 plate member with the fixed pitch.

1 29. The liquid ejection head as set forth in claim 28, wherein each of the  
2 dents is formed in the vicinity of the through hole.

1 30. The liquid ejection head as set forth in claim 28, wherein the plate  
2 member is comprised of nickel.